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Unmanned Aircraft Systems in Supply Chain Management

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Lisbon, 4th January 2019

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Abstract

Nowadays, Unmanned Aerial Systems (UAS) – or colloquial “drones” – in the shape of small cargo carrying quadrocopters can be found in advertisements and R&D reports of many logistics or supply chain management companies. However, the mass deployment of these “cargo drones” is far from becoming reality, while UAS are actually offering many more opportunities to improve Supply Chain Management. This paper provides an introduction to various use cases of UAS in general and examines whether some of these use cases may be able to solve major challenges in future supply chains. Finally, economically viable opportunities for UAS in supply chain management will be presented.

Keywords

Supply Chain Management, Drones, Unmanned Aerial Vehicles, Digital Supply Chains

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List of Abbreviations

ATM	Air Traffic Management
SCM	Supply Chain Management
UAS	Unmanned Aircraft System
U.S.	United States of America

1 Introduction

1.1 What is a drone?

When speaking about drones, people tend to think of little quadrocopters[1] that are making pictures or delivering Amazon shipments to the house door or large unmanned aircraft for military purposes. This first association however only covers a small share of all civil drones out there.

Historians suggest different possible roots of the word “drone”. While some think it originates from World-War-II describing unmanned aircraft used as practice targets during defence drills (AviationWeek, 2016), others see the roots of the word in the male bee that creates humming sounds similar to a drone (Biermann & Wiegold, 2015). However, all derivations of this word share a clear focus on aviation.

In contrast to that, more recent drone definitions suggest that this word describes all unmanned vehicles (aeronautical, ground-based or naval) that are either remotely controlled by a human or acting autonomously (Biermann & Wiegold, 2015 and Bendel, 2018). Although ground-based or naval unmanned vehicles might be of interest for supply chain management as well, I will limit the scope of this thesis to unmanned aircraft systems (“UAS”) and henceforth use this more distinct term – with few minor exceptions.

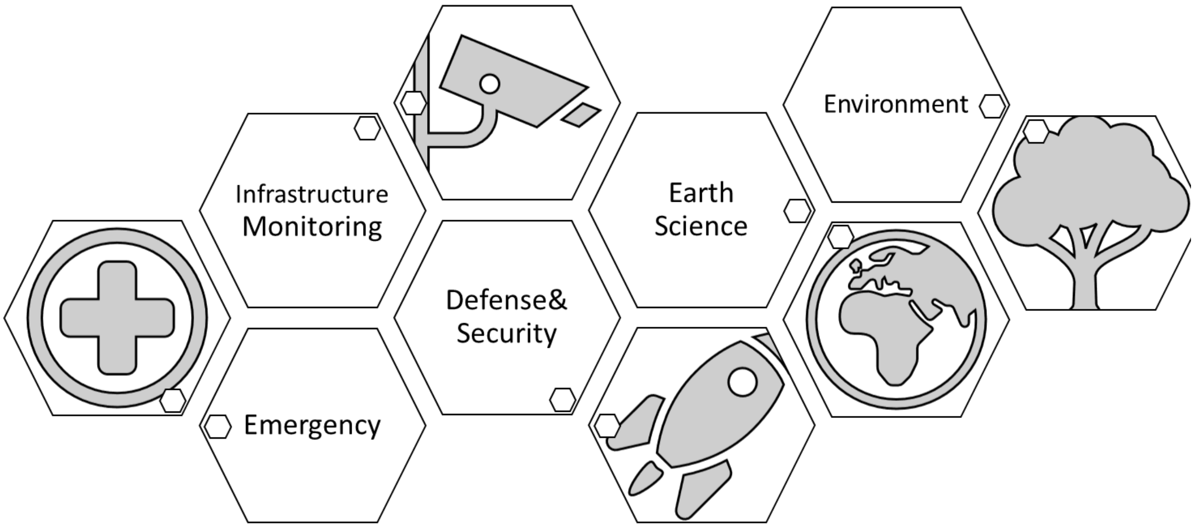
Nowadays UAS can be found in very different shapes, sizes and motorizations, ranging from large fixed-wing and armed fighting UAS to small quadcopters used for hobby photography. One useful criterion to differentiate these UAS is their steering mechanism. Most of the UAS in today’s world are remote-controlled by a human being that has at any time the full control about flight path and actions of the drone. This implies that the major benefit of these UAS does

[1] Rotorcraft aircraft with four vertically operating rotors generating the lift

not lay in their automation, but in their ability to reach places that are either too dangerous, too difficult or too costly to reach for humans. Only very few UAS are used in completely automated settings meaning that they are following certain missions that are defined or controlled by a computer (on-board or on-ground). This conclusion will provide us further insights to the opportunities of UAS in supply chains later.

Another useful categorization of UAS according to their field of application was suggested by Mitka and Mouroutsos in 2017 (figure below). Interestingly none of their categories is called supply chain management or transportation and only the first three out of these five categories are somewhat related to it. Thus, nowadays UAS seem to create comparably much higher benefits in fields other than supply chain management.

Figure 1: Categorization of UAS according to Mitka and Mouroutsos (2017), Own Illustration



1.2 Problem Definition and Research Questions

When being asked which megatrends will shape our future, all major consultancies (naturally) come up with their own roadmaps. However, among all these outlines for the future, we will find ***Technological Development***[2] and ***Limitations of Urban Areas***[3] to be highly critical

[2] "Digitization" (BCG, 2016) / "Rise of Technology" (PWC, 2016)/ "Accelerating Technological Change" (McKinsey, 2015)
[3] ("Infrastructure Scarcity" (BCG, 2016) / "Accelerating Urbanization" (PWC, 2016) / "The age of Urbanization" (McKinsey, 2015))

factors. In consideration of these two megatrends it is not surprising that many people see a big potential in UAS: On one hand the continuous technological development of recent years increased the performance of UAS tremendously while decreasing its cost. On the other hand, the usage of UAS seems to be promising in using limited urban areas more efficiently and by that also revolutionizing todays supply chains. This vision seems very intriguing and companies such as Amazon (Amazon, 2018) and UBER (Resinger, 2018) put a lot of effort in developing drone technologies that can cater for urban supply chains and urban transportation. However, these ideas are still facing various real-life limitations and are far away from creating societal and commercial benefit. Even besides these campaigns attracting most media-attention, it has already been addressed in the introduction to this paper that -as of today- supply chain management only seems to be a minor area of application for UAS. With constantly improving technologies and lowering prices this situation may however change. Thus, this thesis aims in investigating the following research questions:

1. Up to which point UAS may be able to solve major challenges in future supply chains?
2. Which economically viable opportunities for UAS in supply chain management do exist?

1.3 Methodology

The target of research question one is to scientifically verify whether the subject technology will impact a target industry in future. In order to do so, firstly a literature review will be conducted. Within this literature review an introduction to the technology will be given and the general abilities of the technology will be assessed. Based on this review the strategic strengths and drawbacks of the technology will be derived. In a second step qualitative interviews with experts from various fields of supply chain management will be conducted to find out up to which degree UAS do already play a role in their fields of operation today and which value they grant this technology in the future. These interviews will be supplemented by reviewing current news and assessments in the trade and supply chain press. Based on this research and my own findings an overview of current and future use cases for UAS in supply chain management will be given.

Finally, the relevance of these potential use-cases will be compared to the relevance of other new technologies in the supply chain sector. Based on this comparison and the analysis of the potential use cases an inductive conclusion with respect to the first and second research question will be presented.

2 Capabilities of the UAS Technology

2.1 Relevance of UAS

2.1.1 Small Civil UAS[4]

According to the statistics and research company Gartner (2017) the total sales revenue for small civil UAS of a bit more than 4,5bn US$ in 2016 will cross the 11bn US$ mark already by 2020. While the excessively larger number of UAS currently is (and will in the future be) produced for private household use, commercial UAS make up for more than 50% of the total revenue generated with the sales of UAS globally. (Gartner, 2017) Another study estimates that once UAS are fully integrated into the United States National Airspace System, this new industry can create up to 100.000 direct and indirect jobs alone in the U.S.. (Darryl Jenkins, 2013) Furthermore, the availability of this new technology can have a considerable commercial impact for various businesses.

UAS for private use have already been on the market for longer than one would expect: These first private UAS came mostly in shape of model aircraft, were remote controlled through visual contact and had barely other benefits than the amusement of its owners. After the year 2012 the market however started to take off when the first low-priced quadrocopters able to carry high-

[4] Aircraft for private or commercial use with MTOW (Maximum Take-Off Weight) < 25kg

quality cameras became available. These machines were able to lift-off vertically and remain on a steady position in the air. After that various producers recognized the business potential and quickly began offering additional features such as live video streaming, autopilots, automatic obstacle avoidance etc.. (BusinessInsider, 2016) Based on these developments in the private-use sector, civil UAS became interesting for first commercial applications such as surveillance and maintenance prediction.

However, according to McKinsey (2017) the majority of technologies that are crucial for commercial use of UAS (such as *Integrated Air traffic Management*, *Battery Performance* or *Autonomous Flying*) are still far away from their development peak. As an example the capabilities of batteries are still improving every year by around 5 to 8%. (Zu & Li, 2011) Once major improvements will have been achieved in all of these fields, the commercial and economic relevance of UAS will see a further boost.

2.1.2 Large Civil UAS[5]

Larger civil UAS that could be used for the commercial transportation of freight, big surveillance equipment or even passengers do not exist to date. Solely a few UAS originally designed for military missions have been converted into observation aircraft for various scientific purposes. (NASA, 2017) However, according to NASA (2017) alone in the U.S. more than 50 different organizations are performing research for the development of large UAS.

While Airbus recently launched an UAS project called Skyways with the aim to deliver larger shipments shore-to-ship (Airbus, 2018), Boeing representative Steve Nordlund claimed that autonomous flying technology enabling airliners with one-pilot-cockpits are already in development. (Batchelor, 2018) Although completely pilotless passenger aircraft crossing oceans may be hard to imagine nowadays, unmanned cargo flights could be a first step. At the

[5] Aircraft for private or commercial use with MTOW (Maximum Take-Off Weight) > 25kg

same time companies such as UBER are putting a lot of effort into the development of unmanned quadrocopter taxis. (Resinger, 2018)

Although larger UAS are to date economically much less relevant than their smaller siblings, a clear trend to a growing importance of them in our future world can be observed here as well.

2.1.3 Military UAS

UAS for Military missions have always played a much more important role than in civil areas of application. The first usage of a (of-course very basic) UAS in a battle dates back to the year 1849. The reason for the popularity seems simple: UAS are able to conduct way riskier and less restricted missions without risking the life of human soldiers. (Biermann & Wiegold, 2015). According to a current research report by Global Market Insights (2017) recently passed the 13bn$ threshold and is expected to grow more than 10% p.a. until 2024. Compared to this number, the market size of small civilian drones seems very small. Since this paper focuses on the opportunities of UAS in SCM we will however limit the analysis of military usage of drones.

2.2 Use Cases for UAS

Within this chapter an overview of selected civil real-life applications with economic benefit shall be given. Although already today way more use cases exist, the following examples will characterise the commercial relevance of the major capabilities drones currently have. The analysis of these use cases will help to better understand the opportunities that will arise in SCM.

2.2.1 Reaching Inaccessible Places

Figure 2: Flyability Drone[6]

Flyability is a Swiss based UAS manufacturer offering quadcopters that are able to navigate in very narrow spaces. The major drawback of regular quadcopters is that they are very sensitive against collisions, meaning that they crash once a rotor strikes an obstacle. This makes it impossible to use these UAS in target areas with many obstacles. Flyability recognized this weakness and developed a construction that protects the drone from colliding with obstacles. This system opens a large number of new application areas for camera UAS ranging from the maintenance of nuclear power plants to the exploration and mapping of mines. (Flyability, 2018).

According to several customers this UAS is of high commercial value for them: In the case of underground mining a customer claimed that the Flyability product can **cut down exploration times from several days to only one hour**, while delivering considerably better information that can **save up to millions of Euro**. (MacKinnon, 2017) In another use case from Barcelona, the drone descended into Barcelona's sewage system to search for leakages or congestions. While the company responsible for the sewage system maintenance asserted that for regular inspections the cost of using the drone were 40% lower compared to manual work, the major benefit lay in responding to emergencies. In case of pipe bursts, localizing the damage and planning immediate repair was very difficult and time consuming. Nowadays the company can respond immediately. (Flind, 2018)

[6] Source: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcS6F5brmhXGXzNU6P8NUqnuV6ethtLp2uZQ2gaJUjzQQbTnMeZMTw

2.2.2 Insurance Industry

Unmanned aerial systems are relevant for todays insurance industry in two different ways. Obviously the more expensive UAS become and the more risks are associated with them, the higher the importance of proper insurance becomes. Thus, insurance companies can unleash a completely new market. More interestingly for this thesis however: Insurers are making use of UAS equipped with various cameras and sensors for assessing risks and regulating damages. (Baraniuk, 2018) When submitting a house insurance offer, no agent will need to perform a site visit anymore in order to the evaluate location specific risks. More importantly, in case of major damages after natural catastrophes the insurer can overfly the area to evaluate the overall damage and handle insurance claims from aggrieved parties immediately.

The commercial potential seems huge. According to Deloitte (2018) using UAS cut down the claim handling time from a US-based insurer to 4,5 days. Overall, drone technology may save the insurance industry up to $US 7bn annually.

2.2.3 Agriculture

The two aforementioned use-cases for UAS focused on the ability to carry cameras or other surveillance equipment. However, these small aircraft are also able to carry freight. While this is still problematic in urban areas as explained in the Introduction, it is a perfect capability for agriculture in rural areas as the risk of colliding with other aircraft or harming humans on the ground is comparably low. In the agriculture industry drones are mainly used for crop surveillance and crop protection. (Pederi & Cheporniuk, 2015)

Today's high yield focused agriculture requires crop protection in form of insecticides, fungicides or herbicides. These treatments need to be applied evenly in small quantities above the entire fields. While in the past this task was for large fields often performed by agriculture aircraft, today UAS can take over this task more precisely with lower operating costs. While in Japan -due to its very fragmented production areas- already in 2015 more than 40% of the fields were sprayed by UAS, in other areas of the world the maximum payload of these small aircraft seemed to be too low for a commercial use. With improving technology this will however change. (Pederi & Cheporniuk, 2015) Furthermore, UAS in agriculture are very useful when it comes to checking soil quality, surveying irrigation and coordinating ground-based vehicle such as harvester or planter.

Although Freeman & Freeland (2015) concluded that the potential of UAS in agriculture was first overvalued when this technology emerged, they agreed with others (Mogili & Deepak, 2018 and Pederi & Cheporniuk, 2015) that for specific areas of application, UAS will create a considerable commercial benefit.

2.2.4 Disaster Response

Smaller Unmanned Aerial Systems do not require extensive infrastructure and are ready to be used at possibly any location in the world once they arrive there. Thus, there are great opportunities to use this technology in disaster response. These opportunities were however not only recognized recently: Murphy (2014) listed between 2005 and 2014 21 different disasters were 26 different UAS were used mainly for victim search missions, but also for mapping and analysing the destructions. This helped in the end to save many lives and facilitated relief works on the ground.

As in the previously described use-cases, improving technology enabled additional applications: With increasing payloads of small, infrastructurally independent UAS over the last years, they are now able to transport urgently required goods such as food or medicine into areas with interrupted infrastructure. Chowdhury et.al. (2017) took this as an opportunity to develop a model that helps to rapidly build up UAS distribution networks in regions that experienced a bigger disaster. According to them UAS can be an economically and technically viable response to the isolation of areas after catastrophes.

Another possible emergency where deploying UAS could improve todays efforts tremendously are pandemics. Similar to the situation where roads become inaccessible after natural disasters and thus the transport of urgently required goods on the ground is impossible, certain regions in the world do in general not have road access. If diseases break out in these regions it is often impossible to distribute vaccinations or medication quick enough within the available budget. In their study Haidari et al. (2016) concluded that "*implementing a UAS could increase vaccine availability and decrease costs in a wide range of settings and circumstances if the drones are used frequently enough to overcome the capital costs of installing and maintaining the system.*"

2.3 Strategic Strengths of UAS

In the previous chapters a differentiation for civil UAS and various use-cases were presented. To identify whether the capabilities of UAS that enable these obviously commercial and societal beneficial use-cases can create value for SCM, we need to detect the underlying strategic strengths of this technology. Based on the literature review we can state that there were two major reasons that let to the adoption of UAS in today's areas of application:

UAS are either

1. Increasing **efficiency through full or partial automation** of work that had to be previously performed by humans, or
2. Increasing **effectiveness by performing tasks remotely controlled** that were before either too dangerous, too difficult or too costly to be performed by humans.

McKinsey (2017) aimed to forecast the impacts of UAS in five different categories based on interviews with industry experts and own intelligence. The results are shown in table 1 below.

Table 1: Impact of UAS in Areas of Application
(Own illustration based on McKinsey (2017))

Application	Impact	Maturity
Surveillance	High ⬆	Mature / 5 years
Operations	Medium ⇨	Mature
Entertainment/Advertising	Low ⇩	Mature
Multimedia Signal Emission	Low ⇩	in 1-3 years
Transportation/Delivery	High ⬆	in 5-15 years

The use-cases described in this paper support the findings from the McKinsey study as all four of them are related to the category surveillance, while the last two carefully make use of a UAS capability to carry payload as well. Furthermore, the table proofs that for the category surveillance the majority of possible use cases is already enabled, while the maturity of UAS in the transportation sector will only be reached in 5-10 years for goods and 10-15 years for passengers. Thus, it is not surprising that examples for Transportation UAS described in this paper are still in the fledgling stages.

2.4 Challenges for the Mass Deployment of UAS

SESAR - a Europewide programme to improve air traffic management (ATM) in the EU – identified 4 pillars which are crucial to the future success of UAS in Europe, namely **Technology, ATM, Regulation** and **Societal Acceptance**. (SESAR, 2016) In the following an overview will be given which challenges the UAS technology will face within these pillars.

2.4.1 Technology

Undoubtedly the technological development in unmanned aviation during the last years was enormous. Today UAS for civil purposes are much cheaper and more capable than 10 years ago. However, in order to make these systems more independent from human steering on the ground, some technologies need to be developed further: Firstly, the majority of drones today is not able to fly autonomously. In order to automate work this will however be a crucial skill. (McKinsey, 2017) Secondly, todays energy storage in particular for smaller UAS is too inefficient. The weight of batteries reduces the payload and range of the aircraft. Furthermore, the overall capacity of batteries is not high enough to carry a lot of goods over a longer distance. Thus, either the capacity of batteries increases, or other energy carriers must be used. Lastly, the navigation equipment needs to become more reliable in avoiding mid-air collisions and navigating in areas without GPS coverage.

2.4.2 Air Traffic Management

Todays Air Traffic Management systems are not ready for managing thousands of independent UAS flying on well below the coverage of current ATM radar. Furthermore, the level of professionalism among the humans handling the UAS is still very low compared to conventional aviation. The program SESAR (2016) suggests on one hand to develop technology that can be implemented into each UAS, such as detect-and-avoid software or IT security tools. On the other hand they ask for the development of a central ground-based Air Traffic Control system that can coordinate the movements of the UAS – similar to traffic lights on the ground. Additionally, quality assured trainings and licenses for humans handling UAS need to be enforced.

2.4.3 Regulation

Commercial Aviation is one of the most regulated and strictly controlled industries in the world. This makes intuitively sense as the sensitivity of systems and potential damages are high compared to other modes of Transportation. Thus, integrating UAS into Commercial Aviation legislation is not easy and today considered as one of the biggest challenges for the international mass deployment of UAS. (McKinsey, 2017; Rao, Gopi, & Maione, 2016 & EASA, 2018) In general there are three different fields of civil aviation regulations: Operations, Engineering/Production and Commercial. As of today rules and requirements for the operation of UAS are in most countries still very basic: Often not even proper training for the handling of drones or a certification of UAS operating companies is required. On the other hand, economically interesting activities such as independent flights or flights above densly populated areas are – with some exceptions - forbidden in the EU. (EASA, 2018) Furthermore, no structured quality-control for the production or airworthiness of UAS exists, making it difficult to allow new/bigger UAS to perform missions with higher potential damage (e.g. transporting cargo). Commercial regulations define national and international standards for the scheduled airtransport of freight and passengers such as traffic rights, fare systems, passenger rights etc.. Since in the forseeable future UAS will only be used for well-defined local missions, commercial regulations for UAS technology will be of minor importance.

2.4.4 Societal Acceptance

The Societal Acceptance of UAS technology is in general tied to the creation and enforcement of proper regulation. Only when governments can assure that risks for the population (hacked, damaged or off course UAS) of mass deployment of UAS are low, they will start to accept them. (Rao, Gopi, & Maione, 2016) Furthermore, the ability of small quadcopters to take pictures from basically anything is disturbing to most people. Thus, whenever a UAS comes in sight the fear to be spied may exist. These privacy concerns need to be addressed. (Finn & Wright, 2016) Lastly, the Ethical questions that apply to all automated modes of transportation may be another obstruction to societal acceptance: Who is responsible in case of accidents? Will the UAS in case of emergencies rather protect uninvolved bystanders/property or the payload?

2.5 Technological Outlook

The most relevant technological developments in the field of UAS will according to industry insiders be made in the areas that are crucial for the future mass deployment of drones *(see 2.4.1 Technology)*. Some drone manufacturers are working on adapting the Commercial Aviation Technology ADS-B (automatic dependent surveillance broadcast) to UAS and by that integrating them into existing Air Traffic Management. (Canis, 2015) In 2018, companies such as Vigilant Aerospace Systems[7] or Fortem Technologies[8] launched first detect-and-avoid solutions for UAS. Once these systems are accepted by market and all major regulating bodies, UAS could be enabled to fly into airspaces with higher traffic density.

[7] https://vigilantaerospace.com/products-services-overview/flighthorizon-gcs/

[8] http://fortemtech.com/products/trueview-radar/

While batteries might be a perfect energy storage for UAS used in very short missions, their limited capacity becomes problematic for longer flights with higher payload. As mentioned in *2.4.1 Technology* various producers thus try to increase battery capacities. However, it might be worth thinking out of the box and search for alternative energy carrier: Ballard Power Systems developed a next generation fuel cell system for Boeings ScanEagel unmanned aerial system, which was successfully tested at the end of 2017. (Ballard, 2017) Furthermore, Rolf Bulander (Head of Mobility for Bosch) stated in an interview that his company is concentrating its development efforts on synthetic fuels rather than bigger and bigger batteries. (FAZ, 2018).

3 Applications of UAS in Supply Chain Management

Supply Chain Management is a collaborative process that aims in meeting customer requirements by delivering him a desired product at the right place, at the right time and in the right quantity with complete cost discipline. In order to do so, many players within a Supply Chain network need to work together seamlessly. These players can be clustered in five process groups, namely **Planning, Procurement, Production, Distribution and Customer Interface**. Together these process groups need to create one supply chain process. In order to successfully serve the customers, seven principles should be followed (CSCMP, 2018):

Figure 3: Seven Principles of Supply Chain Management according to CSCMP (2018), Own Illustration

Well working Supply Chain Management is crucial for production companies. If goods are not being delivered in the right quantity, at the right price and at the right place, the production will be disrupted, and/or the customer requirements are not met. The potential commercial damage to companies is enormous. Recent industry trends such as reducing safety stocks and delivering just in time instead made a highly reliable and integrated supply chain even more indispensable. Thus, making changes on a part of a running supply chain usually requires adaptions in other parts as and is always associated with high risks. This complexity represents in general a barrier for the implementation of innovation. In consequence, it is not surprising that UAS are not yet widely used.

3.1 Current attempts for usage of UAS in SCM

So far test cases with UAS that are related to Supply Chain Management only exist within the areas of last-mile delivery, warehousing and infrastructure inspection.

2.4.1 Technology

Processes: Distribution; Customer Interface

Figure 4: DHL Paketkopter[9]

The supply chain segments Distribution and Customer Interface currently face constantly growing challenges with the delivery of goods on the last mile to the customer: Shipment destinations are very segregated (even if 100 packages need to be delivered within the same street, there might still be 50 different houses with a total of 250 different apartments/offices). Furthermore, these destinations lay in areas with congested infrastructures and high labour costs. Thus, todays last mile delivery is one of the most expensive and customer unfriendliest parts of the supply chain

[9] Source: https://www.dpdhl.com/content/dam/dpdhl/en/media-relations/text-generic-1592x896/dhl-paketkopter-norddeich1592.jpg

(Example: I can choose my favourite muesli online out of 566 quadrillion different options[10], but still need to be home the entire day to receive the package) Small, autonomous flying UAS could solve this Supply Chain issue and add considerable value in the logistics industry. Thus, the companies Amazon *(PrimeAir)*, UPS *(Deliver Car Drone)*, DHL *(Paketkopter)* and Alphabet *(XWing)* launched trials for last mile deliveries by UAS between 2013 and 2017. However, none of these pilots made it to mass deployment - yet. Gartner (2017) even expects that "*Delivery Drones Will Comprise Less Than 1 Percent of the Commercial Market by 2020*". The main reasons for this seem to be the same as described in chapter 2.4. Furthermore, it is still doubtable whether UAS engineers within these companies will be able to develop solutions that are more cost efficient than todays delivery trucks. However, in a few special cases such as the delivery of urgently required medical equipment in in remote areas remotely controlled UAS could already demonstrate its abilities.

2.4.1 Technology

Processes: Procurement, Production, Distribution

Within the process segments Procurement, Production and Distribution primary products, production parts or end products need to be stored. Often these goods are kept and organized in warehouses. Trends such as the constantly growing importance of e-commerce make this so-called warehousing even more important. (Scott, 2017) Many of these warehouses were planned and constructed in the last century. Thus, their layout may not be optimal for the implementation of modern procedures such as automated storage and cross-docking which means they lack in efficiency. This however contradicts the purpose of supply chain management to perfectly cater for customer requirements.

UAS in form of small camera quadcopters may help in short and medium term to make existing warehouses more efficient by supporting warehouse workers with inventory management. The

[10] https://www.mymuesli.com/blog/2007/05/01/566-billiarden-muslis-der-rechenweg/

French-Based UAS manufacturer *Delta* in cooperation with *GEODIS* successfully developed a UAS consisting of several quadrocopters eliminating the need for manual labour in locating, counting and monitoring goods in existing warehouses. (Chamlou, 2018)In order to analyse the future potential of UAS in warehousing, it will be highly interesting to observe up to which degree the system will be accepted after its market launch end of 2018. Although this solution seems to be promising in improving local efficiencies, its impact on an entire supply chain is however limited.

Another possible use-case for UAS in warehouses could be the indoor transport of goods from their storage location to the required production or export position. This might be another plug-and-play solution for existing facilities where other automated ground-based transport solutions are not possible or too costly. However, further developments in this area of application require drones with higher pay-load capabilities.

2.4.1 Technology

Processes: All except planning

Robbery and theft are a tremendous risk for the continuity of supply chains. If a container or truck with supplies gets stolen, production may be completely disrupted. Nowadays piracy – in particular around the horn of Africa or along the Nigerian coastline – is in the centre of public focus and even evoked a military mission of the European Union to protect trading routes. (EU NAVFOR, 2018) However, supply chain theft is a much bigger phenomena: van Merle (2015) estimated that already within one year 2.300 cargo theft incidents occur alone in the Greater Paris area – trend upwards. Another study by Ekwall & Lantz (2018) revealed that the majority of incidents occurs en-route, on unsecured parking and on supply chain facilities. To reduce such kind of disruptions it is necessary for companies to protect all parts of the supply chain better.

As explained in chapter 2.2 and 2.3 UAS have the capabilities to improve the robustness of entire supply chains by enabling the supply chain team to monitor every good in the supply chain at comparably low cost, since a Camera UAS can be used much more flexibly than stationary surveillance equipment. McKinsey (2017) even predicted that the long-range usage of surveillance UAS – relevant e.g. for ocean ships or cargo trains - will be available for mass-usage in 2 to 5 years. Considering that it will only be a matter of time until the first provider offers integrated mass solutions that are customized for the use in Supply Chain Management.

The Polish train company PKP launched a first surveillance UAS pilot in 2017. During the trial of “BIELIK”, the theft rate could be reduced by approx. 50%. (PKP Cargo, 2017) A simpler version of a surveillance UAS is already in use at the Abu Dhabi port since 2014. There a manually steered quadcopter collects various information about the port operations and transmits them through WIFI to the security central. (TheNational, 2014)

Finally UAS may be of excellent use for the maintaining critical supply chain infrastructure as already described in the chapter general use cases under 2.2.1.

3.2 Deriving potential future application for UAS in SCM

In the previous chapter it was shown that the UAS technology as well affects the supply chain sector and will most likely shape it to the Better. However, it is obvious that the current effects of this technology are minor and the full potential of UAS in supply chain management has not yet been realized. This might be because for certain applications technology is not yet advanced enough or the regulatory and societal environment do not yet allow certain applications. Keeping in mind McKinsey’s (2017) estimation that these two draw-backs will be overcome within 10 years for most of the application areas, there must be various further application opportunities. Thus, I developed an overview of thinkable future areas of application for UAS in SCM based on the conducted expert interviews, the general research on UAS in this paper and own thoughts. These ideas are structured according to the two strategic strengths of UAS (as identified in chapter 2.3) and the seven principles for successful supply chain management (CSCMP, 2018)

Table 2: Potential Future UAS Applications in SCM (Own Illustration)

Strategic Strengths of UAS / 7 Principles of SCM	***Remotely Controlled Tasks*** [11]	***Automated Tasks*** [12]
Segment customers	--	--
Customize logistics to the customer requirements	• Deliver into areas that seemed too dangerous for regular logistics (e.g. ware zones) • Shore-to-ship deliveries with urgent spare parts	• Long distance transport door-to-door (e.g. important documents) • Pilotless intercontinental cargo transportation (with fixed wing aircraft)
Ensure consistent and up-to-date demand planning	• Know customer demand before he knows it (e.g. collect damage information after natural disasters and adapt production immediately	• Observe inventories outside of warehouses

Communicate quickly to delay customization	• Certify/Control supply chain partners remotely
	    ○ E.g. Supermarket: verify that farmer indeed offers meat from free-range animals
	    ○ E.g. Airfreight: verify that sender produced shipments in a safe environment to avoid safety checks at the airport
		• Diagnose machine breakdowns/supply chain interruption before they occur through machine learning

Manage supplies strategically	• Use rapid UAS transportation as a back-up solution in just-in-time delivery failures and thus avoid supply chain disruptions	---
Ensure consistent technology	---	---
Implement overarching performance management	---	• Collect data for performance management automated through UAS counting or observing and thus support machine learning

[11] Increasing effectiveness by performing tasks remotely controlled that were before either too dangerous, too difficult or too costly to be performed by humans

[12] Increasing efficiency through full or partial automation of work that had to be previously performed by humans

3.3 Assessment of selected potential future use cases

All potential future use cases of UAS in SCM organised in the table above may have the power to improve supply chains. However, based on today's general technical capabilities and the size of potential impacts on supply chains, some use cases are more likely to be realized soon. In this chapter the three most promising use cases should be described more detailed and assessed.

2.4.1 Technology

Certain goods need to be delivered over long distance under extreme time pressure. This applies for example to machinery spare parts, freight documentation, secret data or medicine. Today the special transport requirements for these goods are fulfilled with classic air cargo or even courier solutions (i.e. personally accompanying a shipment from origin to destinations). Both solutions require large quantities of human labour and are excessively expensive. Assuming that UAS will be ready for automated use in last mile-delivery in a couple of years, the regulatory and technical burden for the use in longer-distance door-to-door deliveries is only minor - in particular considering that larger military drones such as the Global Hawk already today offer ranges of more than 20.000 km and vertical take-off aircraft (e.g. quadcopters) a couple hundred kilometres. (Northrop Grumman, 2016)

Within supply chain management two different UAS transport solutions are conceivable: regional door-to-door transport (up to 500km) or inter-regional transport with pilotless aircraft (up to intercontinental range). Today's customer price for regional door-to-door courier services in the developed world lay between 0,80€ and 2€ per km (Postsitter, 2018), while quadrocopters – if operated in an effective environment – bring down this price to 0,30€ per km. (Keeney, 2015)

The savings of using fixed-wing UAS for long-haul air-cargo transportation correspond approximately to the cost of a flight crew.

2.4.1 Technology

Continuous certification and control of Supply Chain partners is essential for companies working with a large number of suppliers such as fast moving consumer goods retailer LIDL. The company spends huge effort on evaluating whether new suppliers adhere to certain production standards, such as ethical animal husbandry, agricultural production without insecticides, hygienic correctness or the protection of production facilities against intruders. (LIDL, 2018) Although UAS are of course not able to automat an entire certification process, they may be useful in ensuring consistency of quality through regular audits. Today these audits can only be performed by human auditors - mostly with prior announcements. UAS however can overfly production facilities more frequently at significantly lower cost to check the adherence to major standards. This could go as far as to make the video-material obtained during these audits available to customers to proof to them that the more expensive meat really comes from “happy cows”.

The same principle may be applied to other supply chains as well: Today airfreight by law must undergo security checks before being allowed onboard of aircraft. However, many people do not know that these checks can be waived if a certified shipper is delivering these goods to the airport. According to many experts this procedure represents a high risk to aviation security and may be banned in some countries. The potential costs occurring would be immense. If however, UAS are able to constantly monitor the production and delivery of “safe shipments” the procedure could again be considered safe and remain in place.

The economic potential of this use case cannot be defined more precisely as the costs for freight security checks as well as supplier audits are non-public information and differ strongly by location. In the conducted expert interviews it was however confirmed that an economic potential for this use case exists.

2.4.1 Technology

The robustness and thus also the usefulness of performance management systems depend on the availability of data along the entire supply chain. Since it is difficult to obtain consistent and meaningful data among a large number of supply chain partners due to different locations, systems and interpretations. Integrated unmanned aerial systems such as described in chapter 3.1.2 could be relatively easy and inexpensive installed in the facilities of all supply chain partners and consequently deliver high quality data to feed a performance management system.

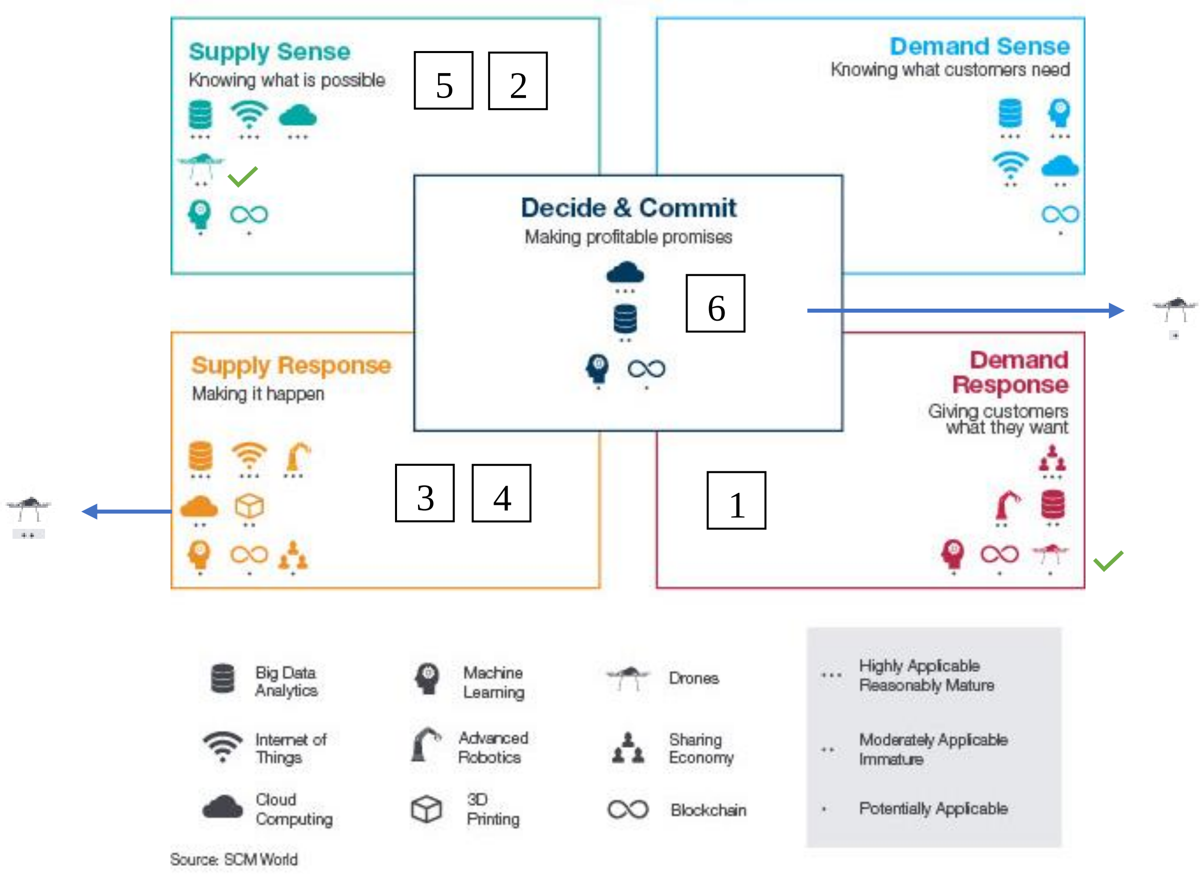
4 Classification of UAS in a Digital Supply Chain

In the previous chapters I have shown that UAS do already play a role in today's supply chains and will become increasingly relevant for future digital supply chains if the technology is developing positively and full potentials are being realised. However, in order to analyse the magnitude of impact UAS can have, it is important to set them into relation with other promising technologies within supply chains. In order to do so I estimated the applicability of the six most promising UAS use cases in SCM within a five-pillar end-to-end supply chain matrix based on SCM World.

Table 3: Overview of Most Relevant UAS Use-Cases in SCM (Own Illustration)

Nr	*Use-Case*	*Relevance*	*Maturity*
1	Last Mile Delivery	High	Low
2	Warehousing	Medium	Medium
3	Infrastructure Inspection	Medium	Medium
4	Long Distance Air Transport	High	Low
5	Remote Partner Certification	Medium	Low
6	Data Collection for Performance Management	Medium	Low

Figure 5: Digitalization in the End-to-End Supply Chain (Source: SCM World, Own Adaptations)



When inserting the six use cases into this matrix, we can see first of all that the full potential of UAS in supply chains was not yet represented. Thus, I am suggesting to extend the graphic with the icons shown on the blue arrows. The slightly adapted graphic shows that UAS may be somewhat relevant for the digitalization of the supply chain. However, when comparing it to key technologies such as the Internet of Things or Cloud Computing, the overall relevance and impact of UAS seems limited. This finding is not surprising considering the fact that all potential use cases found in this study may improve supply chain activities locally but are not revolutionary.

5 Limitations and Future Research

Using UAS technology in a commercial environment is still a very new phenomenon and only on the brink of its break-through. This means that technology, areas of application as well as currently unknown potential opportunities are still very dynamic. Thus, all findings of this paper need to be understood as a snapshot of the present situation at the end of the year 2018. The reader should keep in mind that with any technological break-through, regulatory change or economic change, the today assumed future of UAS in SCM may change considerably. In the scope of this research, it was difficult to find interview partners who are willing to speak about attempts their companies made to deploy UAS. This might be in some cases because of confidentiality concerns, in other cases because pilot cases were much less successful than expected. Indeed, one of my interview partners confirmed that in his company a UAS pilot case is underachieving. Furthermore, it is remarkably that companies such Amazon, Alphabet or DHL spent a lot of effort on communication when they launched last-mile delivery pilots in 2016, but recently became much less communicative.

Unfortunately, the scope of this thesis did not allow for more extensive economic efficiency analysis of the presented use cases. In order to identify the exact potential of UAS in SCM and forecast future developments more precisely, these detailed analyses are highly relevant. Thus, I suggest conducting a research project in cooperation with industry partners to gain access to comprehensive operations data that will be required for a robust analysis. Furthermore, within this paper use cases for UAS were only considered individually. Often, huge improvements in industry operations are only created through the interdependency of several new technologies. Thus, I would like to motivate further research analysing the effects that UAS can have on future SCM when being combined with other key technologies such as machine learning, artificial intelligence or cloud computing.

6 Conclusion

The first research question of this thesis was to investigate up to which point UAS may be able to solve major challenges in future supply chains. Only recently the corporate world discovered the potential of civil UAS: They can help to improve efficiency through automation or increase effectiveness by performing tasks remotely controlled. However, four general challenges to the actual mass deployment of UAS persist: Technology, ATM, Regulation and Social Acceptance. After conducting several expert interviews and reviewing the SCM press, I asserted that already today several use cases exist that aim in solving critical challenges in various process parts of integrated supply chains of the future, such as Distribution/Customer Interface (automating labour intensive and congested last mile delivery) or Procurement/Production (supporting outdated warehouse facilities). Although these use cases seem promising and – at least in the case of last mile delivery - may also have a high impact on supply chains in the future, their maturity is comparably low and the future success uncertain.

The second research question aimed in identifying (further) economically viable opportunities for UAS in supply chain management. Besides these current use-cases, I identified various additional opportunities from UAS deployment for solving current or future challenges in SCM along the 7 Principles of SCM. I could show for the most promising of these opportunities – such as the long-distance air transport or the remote certification of supply chain partners - that they may be economically viable. However, the future success is as uncertain as for the current use cases described earlier. Only if the general challenges for the mass deployment of UAS are solved, these use cases will be sustainably successful and able to improve SCM. With help of an end-to-end Supply Chain Matrix I could also show that the potential leverage of UAS on a digitalized supply chain in the future, is much less significant than the potential of other new technologies

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8 Appendix

<u>Interview 1: Airtransport Professional</u>

Unmanned vehicles in General:

- Aircraft seem to be based on comparably complex technology. Thus, one could assume that unmanned vehicles are much easier to realize for ground-based transport (such as unmanned ships, unmanned delivery cars etc.).
- In your point of view: Is this assumption correct? Will UAS technically ever be able to substitute ground transport for last mile delivery?

UAS supporting the Aviation Industry:

- Do you have a use case example where drones (unmanned aircraft systems) cut costs or enable new processes within your industry?
- Do you think that todays Big players in the Airtransport industry do not investment enough in this technology and consequently risk to loose arising opportunities to newer companies such as Alphabet or Uber?

Personal Opinion on Relevance of "Drones" in the Future:

- In your point of view: Which role will UAS play in the future of supply chain management?
- Will there be a revolution of the last-mile delivery or will the major opportunities from UAS in supply chains arise from support technologies (such as tracking, surveillance etc.)?

<u>Interview 2: Maritime Transport Professional</u>

Unmanned vehicles in the Naval Industry: Aircraft seem to be based on comparably complex technology. Thus, one could assume that unmanned vehicles are much easier to realize in the naval (or ground-based transport) industry.

- In your point of view: Is this assumption correct?
- Do you know of any commercial unmanned ships that are in use today or planned to operate in the future?
- If yes: What where the biggest challenges associated with the introduction of such vehicles? Are they commercially viable?

UAS supporting the Naval Industry:

- Do you have a use case example where drones (unmanned aircraft systems) cut costs or enable new processes within your industry?
- If yes how large is the impact/gain of this technology?
- Did you hear about Skyways' (Airbus) shore-to-ship drone pilot trial? Do you see potential for this project?

Threats to your business model:

- Assuming that costs of transporting goods by air decrease through the use of UAV considerably: Do you consider them to become a threat to your industry?

Personal Opinion on Relevance of "Drones" in the Future:

- In your point of view: Which role will UAS play in the future of supply chain management?
- Will there be a revolution of the last-mile delivery or will the major opportunities from UAS in supply chains arise from support technologies (such as tracking, surveillance etc.)?